

Digital Photography for Urban Street Tree Crown Condition

Neil Clark, Research Forester, SRS 4702 – Forest Products Conservation - nclark@fs.fed.us
Sang-Mook Lee, Researcher, Bradley Department of Electrical Engineering, Virginia Tech - lsmook@vt.edu
Bill Bechtold, Research Forester, SRS 4803 – Forest Health Monitoring - wabechtold@fs.fed.us
Greg Reams, National Program Manager, Forest Inventory and Analysis - greams@fs.fed.us



Introduction

Crown variables such as height, diameter, live crown ratio, dieback, transparency, and density are all collected as part of the overall crown assessment (USDA 2004). Transparency and density are related to the amount of foliage and thus the photosynthetic potential of the tree. These measurements are both currently based on visual estimates and have been shown to be highly variable between observers (Solberg and Strand 1999). Additionally, the collection methods for these variables are not controlled for repeated measures analysis. Digital image capture using relatively inexpensive digital cameras from monumented (using tree as reference) locations is proposed to enable more sensitive analysis of trends in these variables over time by eliminating observer and viewpoint effects. The additional information of crown profiles and spatial distribution of foliage may also provide useful information for modeling.

Why?

Study of tree crowns and the canopy in general is a growing area of research
(Zarnoch et al. 2004, Mizoue and Dobbertin 2003, Ferretti 1997)

Indicator for Santiago Declaration and Montréal Process (Montréal Process 1995)

Why use urban trees?

- Urban setting is receiving greater attention -- visible forestry
- Trees located in areas more susceptible to damaging agents (wind, compaction, mowers, chemical agents/emissions, invasives, etc.)
- Canopy characteristics are different from trees grown in forested condition – i.e. symmetrical
- Canopy position typically not an issue
- Sick Trees + Targets = Hazard Risk (lives and \$\$)
- In public right-of-way so access permission not needed

Photo Methods for Urban Trees from Monumented Viewpoints



T1



T2



T3

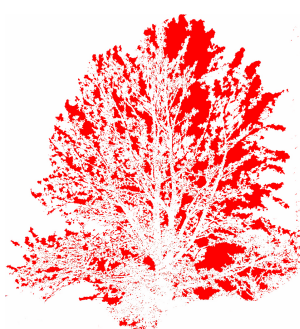
Monumented viewpoints are needed for repeated measures

Creating physical monuments in an urban environment is not often feasible, so the **tree itself serves as the monument** and an offset distance and direction are defined. Previous photos can also be used for proper alignment using points that typically are visible within the branching structure.

Data archive to revisit for *ex post facto* analysis



Change T2-T3

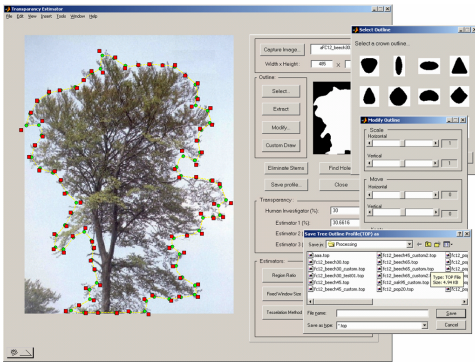


Change T1-T2



Change T1-T3

Digital Processing



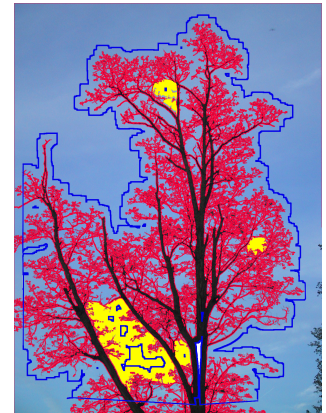
A customized software application has been created which enables:

- ❖ Automated boundary determination
- ❖ Boundary-region archiving
- ❖ Automated tree vs. sky segmentation
- ❖ Many analysis options

Boudary Conformity / Scale :

A very tight boundary conformity in **red** would produce a lower transparency estimate than the looser wrap in **blue**.

Values should be set by species and image scale for consistency.



Gap / Opening Minimums:
The minimum size of opening within the interior of the silhouette (yellow) should also be defined.

Crown Condition Analysis – Area-based

Many terms have been employed to describe the amount and distribution of foliage within a tree crown. Transparency, defoliation, and density are examples. And despite efforts of standardization and harmonization within and among forest health monitoring programs of many countries, no *de facto* standard exists. The primary problem is to attempt to judge the volume of foliage using 2-D ocular methods from ground-based observation points. This basic issue is complicated by biological meanings conveyed by the position of this foliage volume within the crown architecture, and the condition of the foliage volume compared to "normal" conditions (i.e., leaf size, rolled or necrotic foliage, etc.)



Area Ratio

This basic measure is represented by,

$$\frac{\text{Area of sky}}{\text{Area of crown structures}}$$

within the defined boundary.

This measure is analogous to **transparency**, the representation of the amount of skylight visible through the live, normally foliated portion of the crown, as collected by the USDA Forest Service (USDA Forest Service 2004).

Silhouette Area

The area of crown structures represented on the 2-D visual plane has been successfully used to model leaf area (Lindsey & Bassuk 1992, Peper & McPherson 2003) and crown density (Wagar & Heisler 1986).

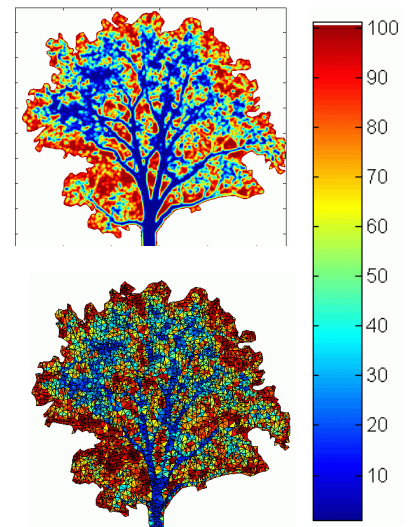
Transparency Distribution Maps

Point-wise

Generated from the mean transparency within smaller, square areas (windows). This gives a representation of the crown structural concentrations within the crown-space. Use of multiple window-sizes can be used to estimate lacunarity.

Region-wise

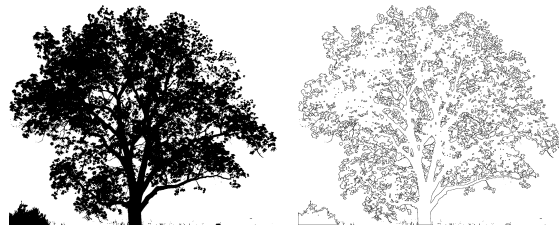
Generated by creating variable-sized, triangular tessellations. The vertices of these triangles are determined using the center points of areas defined using a watershed transformation. This can be used to represent the crown area more efficiently.



Crown Condition Analysis –Morphologic Approaches



Area Ratio: 32% DSO:0.22 Compactness: 35177



Area Ratio: 28% DSO:0.30 Compactness: 20505

Morphologic approaches evaluate the crown complexity using shape-analysis techniques. Morphologic approaches eliminate the previously mentioned problems of defining boundary conformity and gap size parameters. Scale will continue to be an issue as digital images are spectrally and spatially quantified into discrete pixels.

Mizoue (2001) proposed **DSO, the difference between the fractal dimension of a crown silhouette to the fractal dimension of the crown outline**. DSO decreases curvilinearly as transparency increases and is more sensitive at lower levels of transparency.






Compactness, defined as,

$$\text{perimeter}^2 / \text{area}$$





is another shape descriptor that correlates with transparency. This measure increases in sensitivity at higher transparencies.

This example demonstrates the characteristics of area and morphological methods. Blue line represents outline for area methods.





- Due to boundary conformity, area-based methods will report some amount of sky visible, even if entire silhouette is filled.
- Area estimates are consistent within the defined space (which is good for repeated measures), however lacks descriptiveness as there is no information of how the crown structures are clumped.
- DSO is better for dense crowns, compactness for sparse crowns

	A	B	C	D	E
					
Area Ratio:	95%	48%	48%	48%	48%
DSO:	1.00	1.00	0.65	0.47	0.00
Compactness:	16	13	85	221	11250

Summary

-  Precise and reliable foliage volume and distribution change estimates can be attained using digital photo monitoring techniques from monumented viewpoints
-  An extensive amount of primary data can be collected rapidly
-  Monumented viewpoints are easy to relocate using digital imagery.
-  Image archives are also useful for verification and qualitative assessment over long periods of time

Future Research:

-  Develop the best models for particular species or species groups with similar crown characteristics
-  3D graphical modeling software will be used with detailed tree crown data to simulate various effects.
-  Explore use of leaf-off images for ramification quantification
-  Boundary conformity and optical scale effects will be examined

Literature Cited:

- Ferretti, M. 1997. Forest health assessment and monitoring – issues for consideration. *Environmental Monitoring and Assessment*. 48(1): 45-72.
- Lindsey P. and N. Bassuk. 1992. A nondestructive image analysis technique for estimating whole-tree leaf area. *HortTechnology* 2: 66–72.
- Mizoue, N. 2001. Fractal analysis of tree crown images in relation to crown transparency. *Journal of Forest Planning*. 7:79–87.
- Mizoue, N., and M. Dobbartin. 2003. Detecting differences in crown transparency assessments between countries using the image analysis system Croco. *Environmental Monitoring and Assessment*. 89(2):179-195.
- Montreal Process. 1995. Criteria and indicators for the conservation and sustainable management of temperate and boreal forests. Hull, Quebec, Canada:Canadian Forest Service. 27 p.
- Peper, P. and E. McPherson. 2003. Evaluation of four methods for estimating leaf area of isolated trees. *Urban For. Urban Green*. 2: 19-29.
- Solberg, S., and L. Strand. 1999. Crown density assessments, control surveys and reproducibility. *Environmental Monitoring and Assessment*. 56:75-86
- USDA Forest Service. 2004. FIA Field Methods for Phase 3 Measurements, 2004. USDA Forest Service. URL: < <http://fia.fs.fed.us/library/field-guides-methods-proc/>>, (date last accessed: 1 August 2005).
- Wagar, J.A., and G.M. Heisler. 1986. Rating winter crown density of deciduous trees: a photographic procedure. *Landscape J*. 5(1):9-19.
- Zarnoch, S.J., Bechtold, W.A., and K.W. Stolte. 2004. Using crown condition variables as indicators of forest health. *Can. J. For. Res.* 34:1057-1070.